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Effects of Visual and Geometric Cues in Rat Foraging

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EFFECTS OF VISUAL AND GEOMETRIC CUES IN RAT FORAGING

by

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Department of Psychology

Submitted in Partial Fulfillment

of the requirements for the degree of

Bachelor of Arts

in

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Abstract

The purpose of the current study was to investigate cue competition in rat foraging. Rats were placed in a food tower maze comprised of 25 towers arranged in a 5 x 5 matrix. Four towers within the maze were baited and arranged in a diamond spatial pattern. The rat's objective during each trial was to find each baited tower. The rats in the Visual + Pattern (V+P) condition had an additional, visual cue in the form of striped sleeves placed on all four baited towers. There were 80 trials in total, split into two phases of 40 trials. Rats in the V+P group had the baited towers marked with stripes during Phase 1 and these visual cues were removed during Phase 2. Rats in the Pattern Only (PO) group had no visual cues identifying baited towers in either Phase 1 or Phase 2. Results of the experiment indicated that the V+P group significantly outperformed the PO group during Phase 1 in terms of choices required to find the fourth baited tower. During Phase 2, both groups of rats decreased in performance. However, there was no significant difference~~s~~ between the two groups of rats during Phase 2. Thus, the V+P rats learned the pattern in spite of the visual cues, demonstrating that salient visual cues did not overshadow less-salient pattern cues.

Acknowledgements

This thesis could not have been completed without the assistance of a few key individuals. First, I want to thank my advisor, Dr. Mark Cole. You have been a great advisor and your attention to detail always kept me on track. I cannot thank you enough for all the patience and support you have given me over this year. You have also made an incredibly academic mentor over the past four years and I cannot thank you enough for all the opportunities you gave me.

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I would also like to thank my friends and family for your encouragement and support over the past year. You were all so eager to hear about the “rat life” and you were always there when I needed a motivation boost. Thank you so much.

Finally, I would like to thank the rats. I know we’ve had our ups and downs, but you guys were fantastic subjects and you deserve all the Cheerios in the world. Thank you for devoting yourselves to this research, you literally ate, slept and breathed this stuff. I will forever more defend your kind whenever I hear someone speak badly about rats.

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Introduction

Early research by Cheng (1986) found that rats learned to use geometric cues to get to a goal location even in the presence of presumably more-salient visual cues. In Cheng's (1986) series of experiments, he placed rats in a rectangular box that had four corners that were differentiated in texture, appearance and odour. The first experiment investigated rats' working memory by tasking the rats with finding the bait hidden in a particular corner. Results indicated that during the majority of trials, the rats either dug at the correct location or made a rotational error and dug at the corner that was diagonally opposite the correct corner, a corner that had the same geometric properties as the baited corner. Such results indicate that the rats did not use the featural - and presumably more salient - cues such as odour and appearance. Rather, the experiment demonstrated that the rats relied on the location's geometric relation to the starting point as both corners were an equal distance from the rat's beginning locations. When Cheng (1986) moved the odour and visual cues 90˚, the rat continued to use the geometric cues rather than following the visual and olfactory cues. These experiments suggest that rats do not tend to rely on landmarks to guide them but relied instead on geometric properties to help them find a target location. These findings led to Cheng suggesting that rats' mental spatial representation is organized in a modular fashion such that there is a specific geometric module in the brain. Cheng theorized that this module encodes the geometric properties in the arrangement of surfaces, the shape of the environment even in the presence of more-salient visual or olfactory cues.

Thus, Cheng's (1986) study demonstrated that the salient geometric cues failed to overshadow the visual and olfactory cues, which violates a mathematical model created by Rescorla and Wagner (1972). The model was developed to predict outcomes when two redundant stimuli served as a compound conditioned stimulus. This model was based on Pavlov’s experiments involving conditioning a neutral stimulus by pairing it with an unconditioned stimulus. Rescorla and Wagner’s (1972) model identified blocking and overshadowing as two outcomes that may result from combining two redundant stimuli. Blocking occurs when a single stimulus is conditioned by being paired with an unconditioned stimulus and then a second stimulus is later added so that both stimuli precede the unconditioned stimulus. The second stimulus does not get conditioned as the associative strength between the first conditioned stimulus and the unconditioned stimulus is already established. Overshadowing occurs when the two neutral stimuli are originally paired with the unconditioned stimulus simultaneously, but one stimulus is more salient than the other and so gains most of the associative strength. Rescorla and Wagner’s (1972) model of associative strength has frequently been cited when investigating whether spatial or visual cues condition better when paired together.

Several studies have investigated rats’ behavior in mazes containing various types of cues to investigate the processes of blocking and overshadowing. Brown and Terrinoni (1996) conducted an experiment in order to investigate whether rats can use the spatial relations among locations in order to find hidden goals. This study was originally conducted in response to the common critique of radial arm maze studies for allowing rats to view and make use of the extra-maze cues in learning and remembering where certain locations are. Brown and Terrinoni (1996) prevented this from occurring by using an enclosed maze apparatus. This maze consisted of 25 food poles set up in a 5 x 5 matrix. To further prevent the observation and use of extra-maze cues, the maze was atop a platform that was rotated in an unpredictable orientation before each experimental trial.

Two experiments were conducted with very similar designs. During the first experiment, only four poles were baited with food and these poles were always arranged in one of the 16 possible 2 x 2 submatrices of the maze. An experimental trial involved placing a rat in the maze, recording which poles the rat checked for food and did not end until all pieces of food had been discovered. An example of a trial can be found in the upper portion of Figure 1. The researchers were primarily interested in determining if the geometric pattern could be learned by the rats. The results showed that after a rat found the first piece of cheese, it checked poles that could be a part of a 2 x 2 matrix more often than chance would suggest.

It was thought that perhaps the rats were not learning the spatial pattern in Experiment 1 and were simply checking the poles closest to the first piece of cheese that was found. Experiment 2 used a different spatial pattern to investigate whether this explanation had merit. During Experiment 2, 20 food poles were arranged in a 4 x 5 matrix and a linear column of four poles was baited with food. An example of a trial can be found in the lower portion of Figure 1. The results replicated that of the first experiment, suggesting that rats are capable of learning spatial patterns.

Brown, Yang and Digian (2002) continued this research to investigate cue competition. The experiment mostly replicated the previous study with the key difference that rats were randomly assigned into two groups: Visual + Pattern (V+P) and Pattern Only (PO). Those in the O group experienced the same trials as in the previous study. Those in the V+P group were given

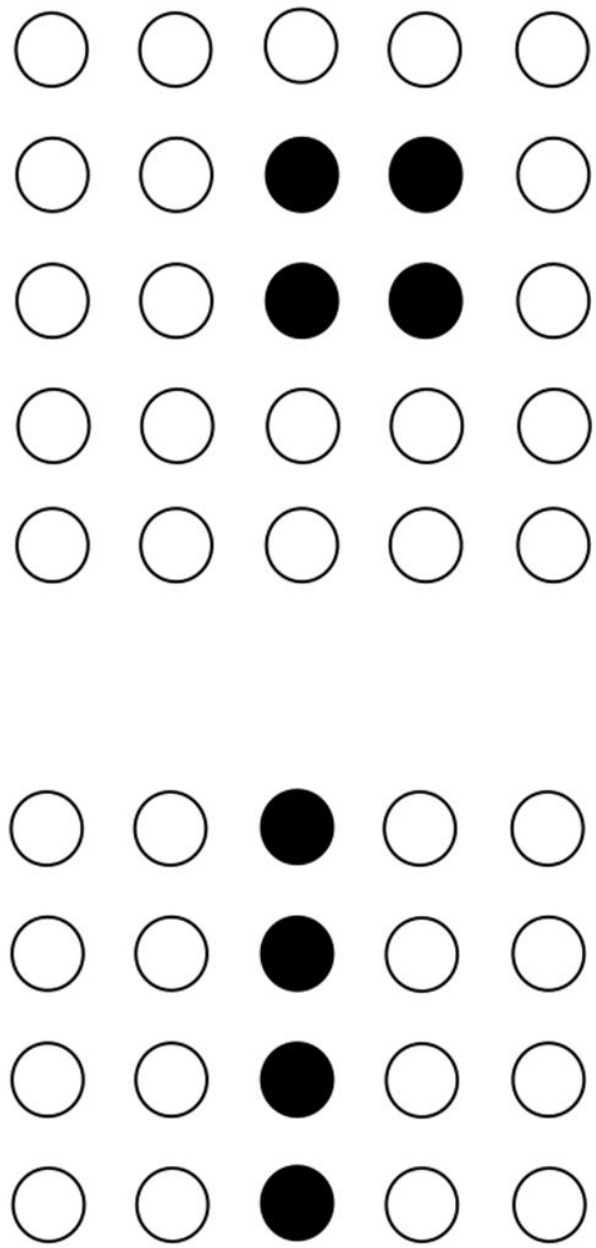

Figure 1. The top matrix is an example of a trial from the first experiment. There are 16 variations of this baited spatial pattern. The bottom matrix is an example of a trial from the second experiment. There are 5 variations of this baited spatial pattern. The circles represent the poles and the black circles represent the baited poles.

a second, visual cue, in that the baited poles were marked with stripes as well as being arranged in a 2 x 2 matrix (Brown, Yang & Digian, 2002). The maze consisted of 16 food poles arranged in a 4 x 4 matrix. Examples of Phase 1 trials for the V+P group can be found in the top portion of Figure 2. In Phase 1, the rats in the V+P condition consistently found food with fewer looks than the rats in the PO condition. During the second phase, however, the striped sleeves were removed for the V+P group. Examples of Phase 2 trials for both groups can be found in the bottom portion of Figure 2. It was found that after the visual cues were removed, the rats that had been exposed to such cues declined precipitously in their performance (Brown et al., 2002). However, their performance only dropped to the level of that seen in the PO group (Brown et al., 2002). Such results indicate that the presence of visual cues did not overshadow the learning of pattern cues during Phase 1.

A more-recent series of experiments was conducted in order to investigate pattern and visual cue competition in rats using freestanding food towers rather than a one-piece maze apparatus (Clipperton, Cole, Peck & Quirt, unpublished manuscript). The first experiment was designed to replicate the experiment by Brown et al. (2002) but with a greater separation between adjacent food sources. Brown et al. had suggested that the effect of the visual markings may have been only to attract the rats to the right general area after which they could simply rear at one tower and rotate their bodies to view the adjacent towers. This replication set the food towers 30 centimeters apart, centre-to-centre. The results replicated the findings of the Brown et al. study, suggesting that the failure to demonstrate overshadowing was not due to the close proximity of the towers.

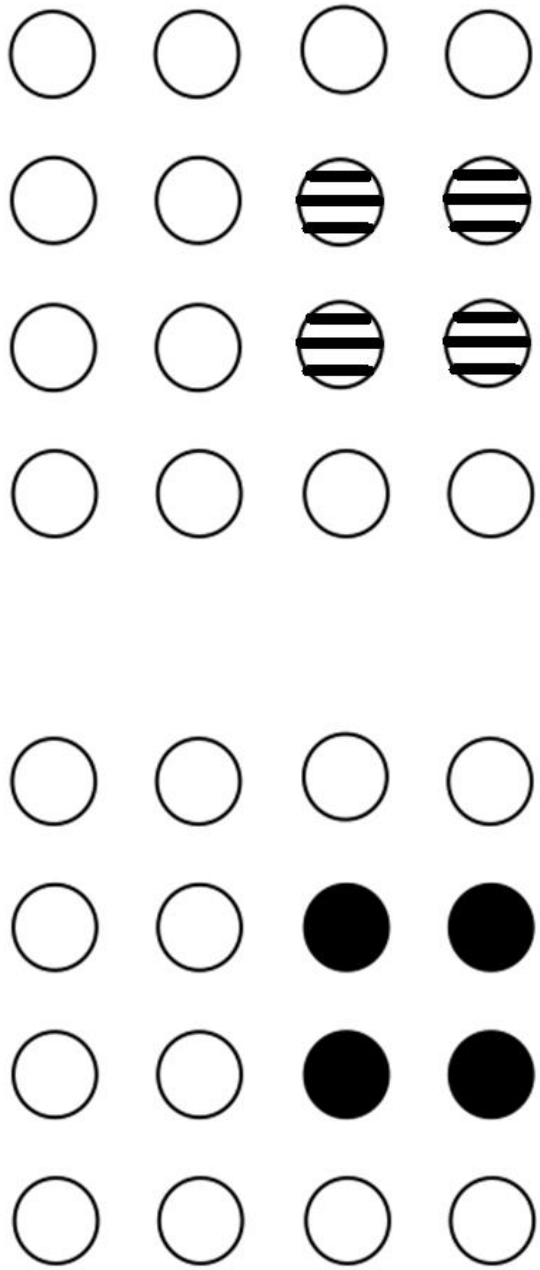

Figure 2. The white circles represent the poles that are not baited, the striped circles represent the poles that are baited and have striped sleeves, the black circles represnt poles that are baited. The top matrix is an example of a trial for the Visual + Pattern group during Phase 1. The bottom matrix is an example of a trial for the Visual + Pattern group during Phase 2 and an example of a trial for the Pattern Only group during Phase 1 and Phase 2.

The second experiment was conducted in order to provide evidence that the visual cues were actually more salient than the pattern cues in this food tower paradigm. Rats were initially trained with trials in which four towers arranged in a 2 x 2 matrix were baited with cheese and marked with striped sleeves. Probe trials were conducted in order to put the visual and pattern cues in competition with each other. During a probe trial, one of the striped towers in the 2 x 2 matrix was displaced such that the fourth tower in the 2 x 2 matrix was not marked with a striped sleeve and a tower adjacent to it was marked with a striped sleeve. Both the tower that completed the pattern and the displaced striped tower were sham baited. The results indicated that the visual cues were more salient than the pattern cues as rats usually chose to search the displaced striped tower before searching the white tower that completed the pattern.

The third and fourth experiments conducted by Clipperton et al. (under review) were designed to investigate whether visual cue learning or pattern learning was stronger. For the third experiment rats were randomly assigned to either the Visual + Pattern → Visual + Pattern Unreliable (V+P → V+PU) group or the Visual + Pattern Unreliable → Visual + Pattern Unreliable (V+PU → V+PU) group. During Phase 1, the V+P → V+PU group underwent the same training as was used for the experimental groups in Experiment 1 by Clipperton et al. (under review) and in the Brown et al. (2002) experiments: four baited towers were arranged in a 2 x 2 matrix and marked with striped sleeves. For the V+PU → V+PU group, the four baited towers were striped but randomly placed throughout the maze. During Phase 2, the baited towers were striped but not placed in a 2 x 2 pattern for either group. The results from Phase 2 indicated that the groups did not differ significantly in performance. That is, placing the striped towers in a pattern during Phase 1 did not facilitate the learning of visual cues. Moreover, the rats' performance did not decline significantly during Phase 2, reiterating the fact that visual cues are important and salient learning cues.

The fourth experiment conducted by Clipperton et al. (under review) was to serve as a direct counterpart to the third experiment in that the visual cues instead of the pattern cues were made unreliable during Phase 2. Rats were randomly assigned to either the Visual + Pattern → Visual Unreliable + Pattern (V+P → VU+P) group or the Visual Unreliable → Visual Unreliable (VU → VU) group. During Phase 1, the V+P → VU+P group underwent the same training as the V+P → V+PU group in Experiment 3. That is, the four baited towers were striped but randomly placed throughout the maze. The VU → VU group experienced trials in which four baited towers were arranged in one of the nine possible 2 x 2 matrix patterns but with no distinctive visual cues and four randomly placed towers were marked with stripes and left without bait. During the test phase, both groups experienced the same experimental trials as the VU → VU group had experienced during Phase 1. The results indicated that the V+P → VU+P group performed significantly better than the VU → VU group during Phase 1. However, the V+P → VU + P group's performance declined significantly during Phase 2. This demonstrated that the visual cues were vital in learning where food was located. Overall, this series of experiments demonstrated that the learning of visual cues was more robust than that of the pattern cues when it came to learning the location of food.

Grogan (2015) was able to demonstrate that rats are capable of using visual cues not connected to baiting to facilitate the learning of a spatial pattern. The study involved eight rats randomly assigned to two experimental groups: Visual Pattern and Visual Random. During a trial, all rats entered the same maze comprised of 16 food towers arranged in a 4 x 4 matrix and had the same goal of finding the cheese atop four towers arranged in a 2 x 2 matrix. There was an additional 2 x 2 matrix of towers that was marked with a striped sleeve when conducting trials with the Visual Pattern group. At most one of these towers was baited but usually none of these towers were baited. For the Visual Random group there were also four towers marked with striped sleeves but they were randomly placed throughout the maze. Examples of trials for each group can be found in Figure 3. On 25% of the trials there was an overlap between a striped and a baited tower while the other 75% of the trials did not involve an overlap. The results indicated that the rats in the visual pattern condition found all four baited towers with significantly fewer looks than those in the visual random condition (Grogan, 2015). It was concluded that the four towers arranged in a 2 x 2 pattern and marked with the highly salient visual cue facilitated the learning - or accelerated the learning - of the 2 x 2 geometric pattern that the baited towers were arranged in.

The study of cue facilitation has also been studied using human participants. A recent study found that a consistent but not coincident visual pattern facilitated the learning of a diamond spatial pattern in humans (Sturz, Kelly & Brown, 2010). This experiment used a virtual reality environment consisting of 25 goal bins arranged in a 5 x 5 matrix similar to the apparatus used in the previous studies (Sturz et al., 2010). Participants were randomly assigned to one of three groups: Pattern Only – four goal bins arranged in a diamond pattern with a non-goal bin in the middle; Landmark + Pattern – four goal bins arranged in the same pattern with the middle non-goal bin possessing a visual cue; and Cue + Pattern – four goal bins arranged in the same pattern and all marked with a visual cue. Examples of trials for each condition can be found in Figure 4. During Phase 1 participants searched for the goal bins and became familiar with

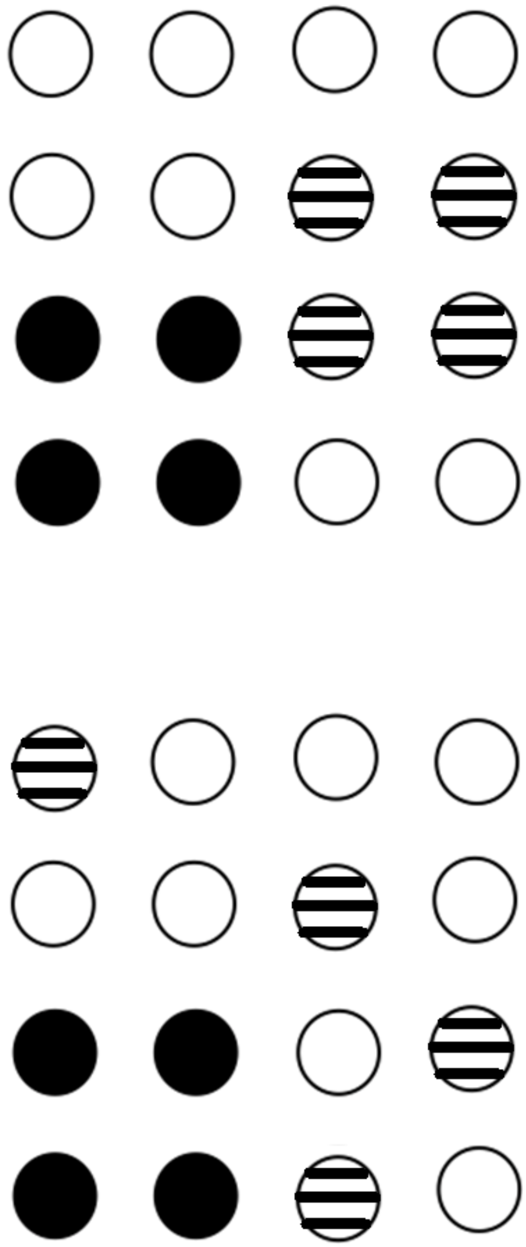

Figure 3. Diagrams representing trials from the Grogan (2015) study. The white circles represent towers without bait. The striped circles represent towers marked with striped sleeves without bait. The black circles represent baited towers. The top matrix represents a trial for the Visual Pattern group. The bottom matrix represents a trial for the Visual Random group.

what cues were available. During Phase 2 all visual cues were removed no matter what condition a participant was in. An example of a trial during Phase 2 can be found in the top panel of Figure 4. The results demonstrated that those in the Landmark + Pattern condition and the Cue + Pattern condition performed very similarly and significantly better than those in the Pattern Only condition during the first phase (Sturz et al., 2010). These results suggest cue facilitation – that the visual cues facilitated faster learning of the geometric pattern and resulted in enhanced performance during Phase 2 (Sturz et al., 2010).

The current study may be conceptualized as a hybrid and a replication. It seeks to partially replicate Brown et al.'s (2002) study as well as the study conducted by Sturz et al. (2010) by combining a few key ideas from both studies. The experiment conducted by Brown et al. (2002) demonstrated that visual cues did not overshadow pattern cues for rats when both experimental groups performed equally during Phase 2. The experiment conducted by Sturz et al. (2010) found that the presence of visual cues actually facilitated the learning of a spatial pattern. By combining components of both studies I hope to determine which differences caused one study to demonstrate facilitation while the other study simply demonstrated a lack of overshadowing: the use of human participants instead of rats; or the replacement of a square spatial pattern with a diamond spatial pattern.

The current study involved randomly assigning rat subjects into two groups: Visual Cues + Pattern (V+P) and Pattern Only (PO). A diamond pattern was used as the geometric cue while striped sleeves served as visual cues. Rats in the V+P group were placed in a 5 x 5 food tower matrix and attempted to find the bait atop striped towers arranged in a diamond pattern. Rats in the PO group engaged in the same task but were not given visual cues. During Phase 2

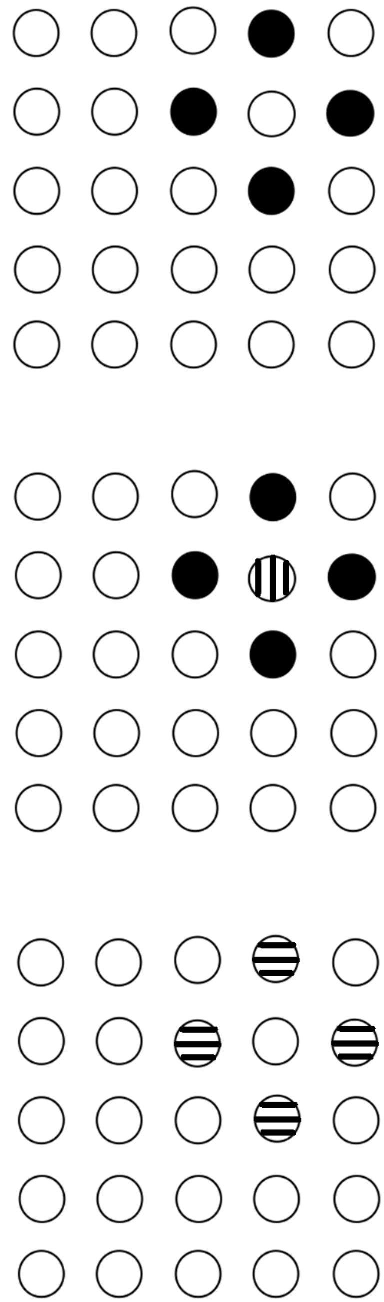

Figure 4. Diagrams representing trials from the Sturz, Kelly & Brown (2010) study. The white circles represent unmarked non-goal bins. The black circles represent baited but unmarked goal bins. The circle with vertical stripes represents a marked non-goal bin. The circles with horizontal stripes represent marked goal bins. The first matrix is an example trial for the Pattern Only group during Phase 1 and is also an example of any trial during Phase 2. The second matrix is an example of a trial for the Landmark + Pattern group during Phase 1. The third matrix is an example of a trial for the Cue + Pattern group during Phase 1.

the visual cues were removed for the V+P group. Of utmost interest was how the rats in the V+P group would perform during Phase 2. If they outperform the PO group it would suggest that facilitation can occur in rats as well as humans when using a diamond spatial pattern. If the V+P group perform at the same level as the PO group during Phase 2 it would replicate the findings of Brown, Yang and Digian (2002), adding further support that visual cues do not overshadow spatial learning even when the geometric pattern is a diamond instead of a square. Further, no previous research has demonstrated that rats can learn a diamond spatial pattern. Finding that rats have the capacity to process more complex cognitive maps would be a great achievement in itself. The performance of the PO rats served as a control and most clearly demonstrated rats' ability to comprehend a diamond spatial pattern. It is currently hypothesized that during Phase 2 rats in the V+P group will significantly outperform those in the PO group, demonstrating a facilitation effect.

Method

Subject

The subjects used for the experiment were 12 male rats (*Rattus norvegicus*) of the Long-Evans strain. They were received from Charles River in Montreal, Quebec and weighed approximately 350 g upon arrival. They were given ad lib. food and water for a few days to establish a free-feeding weight. Then, by calculating 90% of the free-feeding weight, a redline weight was produced. Every Friday, 20 g was added to the free-feeding weight and once again multiplied by 0.9 to account for the rat's natural growth. The rats continued with a restricted diet to maintain their redline weight while various procedures were performed (see Appendix D for the rats' experimental history). When the procedures had been completed, the rats were once again given ad lib. food and water until the current experiment was ready to begin. Preceding the current experiment, the rats' weights ranged from 500 g to 610 g. New redline weights were calculated once again by calculating 90% of these free-feeding weights however they were not increased to account for natural growth as all rats had reached full maturity by this point. Most of the rats weighed slightly more than the redline weight throughout the experiment.

The rats were housed in pairs at The Animal Laboratory at Huron University College. They lived in plastic breeding cages with lids constructed from stainless steel bars. The bottom of the cages contained bedding, Beta Chip ®, from Northeastern Products Corporation (NEPO) in Warrensburg, NY, which was changed once a week. Each cage contained two pipes and nesting material for environmental enrichment. The two black pipes were short lengths of 10-cm-in-interior diameter of PVC pipe. The nesting material was called Crink-l'Nest ™ and manufactured by The Andersons, Inc. in Maumee, OH. The lids of the cages had depressions to hold food and two water bottles. The rats were fed Prolab ® RMH 3000 by PMI ® Nutrition International LLC in Brentwood, MO.

All 12 rats were kept in a cage room together. The room was kept at 23°C with 18 fresh air changes every hour. The lights in the cage room were on a 12-hour light-on-light-off cycle, being off at 4 a.m. and turning back on at 4 p.m. There was also a radio in the room, which was on when the lights were off and was tuned to the French CBC station, which played mostly classical music. The rats were tested almost all of the time when the lights in the cage room were off. The rats were treated in accordance with the ethical standards of the Canadian Council on Animal Care.

Rats 1 through 8 were randomly assigned to one of two experimental groups: Visual + Pattern (V+P) or Pattern Only (PO). Since rats 9 through 12 did not initially engage in pre-study experiments, they had to be equally distribute to the two groups, this was done randomly between the four rats.

Apparatus

The apparatus used for the experiment consisted of 25 food towers. The towers were made of 10.0 cm by 10.0 cm cedar fence posts that were cut into 15.0 cm lengths. The towers were covered in sleeves made from white Bristol Board covered with clear packing tape. During Phase 1 of the experiment, four extra towers were used that were covered by sleeves that also had horizontal black stripes on them, which were made by wrapping black friction tape around the white Bristol Board. The striped towers had three black stripes and two white stripes, each stripe approximately 3 cm wide. At the top of each food tower was a food cup created from a black plastic 35 mm film canister that was cut down to approximately 2 cm in height. Each food cup was 3 cm in diameter. The 25 towers were placed 11.25 cm apart from each other center to center in a 5 X 5 matrix. For each trial, the food cups on top of four towers contained small pieces of cheese. The cheese was President’s Choice Medium Cheddar cut into approximately 0.5 cm^3 blocks.

The experiment took place in a testing room in the animal laboratory. The test room was 2.04 m by 1.19 m. In the middle of the ceiling there were four fluorescent tubes covered by plastic translucent lens that were illuminated during the experiment. The towers were placed on the floor of the room, which was grey coloured industrial grade vinyl. The 5 x 5 matrix of towers was placed such that it was 19 cm away from the rear wall, 11.5 cm away from each side wall, and 23 cm away from the front wall. The side walls of the room were made of cinder block and painted a creamy yellow colour. The rear and front walls were made of green board and painted the same creamy yellow colour as the side walls. There were no clear distinctions or landmarks on the walls other than the door which was on the front wall and which had a small window.

Procedure

Preliminary Phase. Preliminary training began by placing four training towers of various heights into the testing room with cheese placed in the food cups on top of them. The rats were put into the testing room, one at a time, and were observed from the door window. The rats had successfully completed the preliminary training when they found all the cheese and ate it. This was completed in one session.

Phase 1. Phase 1 testing consisted of 40 trials. The rats were originally tested once a day, this was increased to twice a day after Trial 9 with an inter-trial interval of approximately 60 minutes. During a Phase 1 trial, a rat was placed in the test room while an experimenter recorded the order of towers the rat visited and how long it took the rat in seconds to find all four pieces of cheese. The pieces of cheese were always placed at the top of four food towers which together formed a diamond-shaped pattern. The nine possible patterns are shown in Figure 5. A randomly-ordered schedule determined which pattern was used for each trial. There were only four trials that deviated from this order due to experimenters' error: Trials 35 and 36 repeated the patterns used in Trials 33 and 34 respectively, while Trials 58 and 59 repeated the patterns used for Trials 56 and 57 respectively. It is important to note that in these instances the same pattern was never used for two consecutive trials as a pair of patterns was repeated in the same order

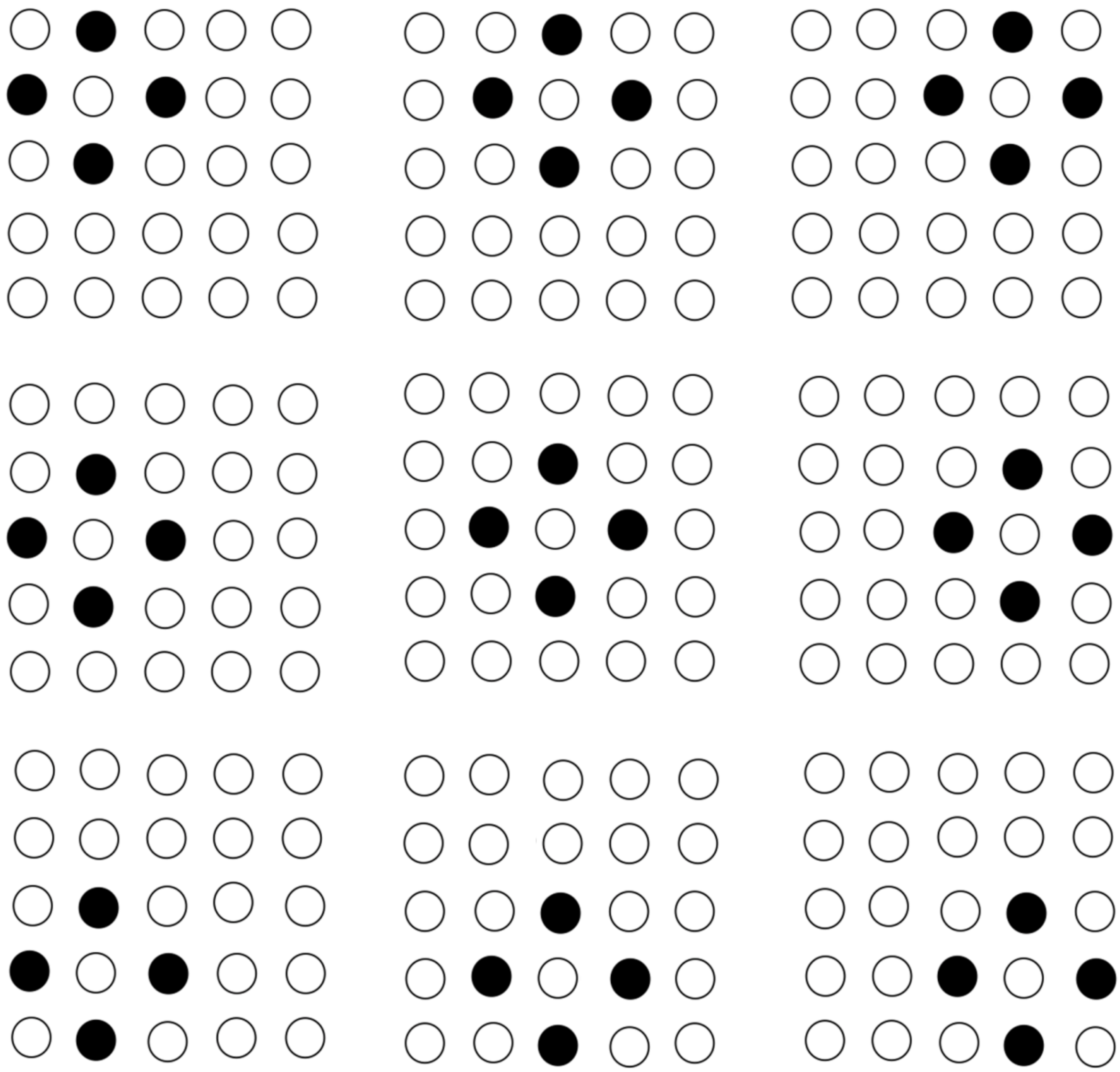

Figure 5. All nine bait patterns used during testing.

each time. During a session of trials, the same pattern was used for all rats. For rats in the V+P group, the cheese was placed atop four food towers that were marked with striped sleeves. For rats in the PO group the baited towers were not marked and appeared the same as all other food towers. A regular trial was deemed complete once the rat had reared up on each baited tower, though it was not required that the bait was consumed by the rat. Trials were also deemed complete if a rat completed 50 CTC, an upper limit calculated by multiplying the number of towers by two.

Phase 2. Phase 2 also consisted of 40 trials. The main difference between Phase 1 and Phase 2 was the absence of striped sleeves for the V+P rats. All rats experienced the same conditions as had PO rats in Phase 1.

All experimental procedures were shared by two experimenters: the author and another undergraduate psychology student with previous experience working in The Animal Lab. One experimenter ran all 12 trials in any one session and the experimenters each carried out about half of the trials in a semi-random fashion.

Results

The number of choices to criterion (CTC) was recorded for each of the rats for all 80 trials. These data were grouped into eight blocks of 10 trials for each rat for analysis and are depicted graphically in Figure 6. During Phase 1, all rats' CTC decreased with each subsequent block. The PO rats' CTC were consistently greater than those of the V+P rats. A 2 x 4 mixed analysis of variance (ANOVA) was conducted for Phase 1 with condition (V + P, PO) as the between-subjects factor and the first four blocks of 10 trials as the within-subjects factor. The

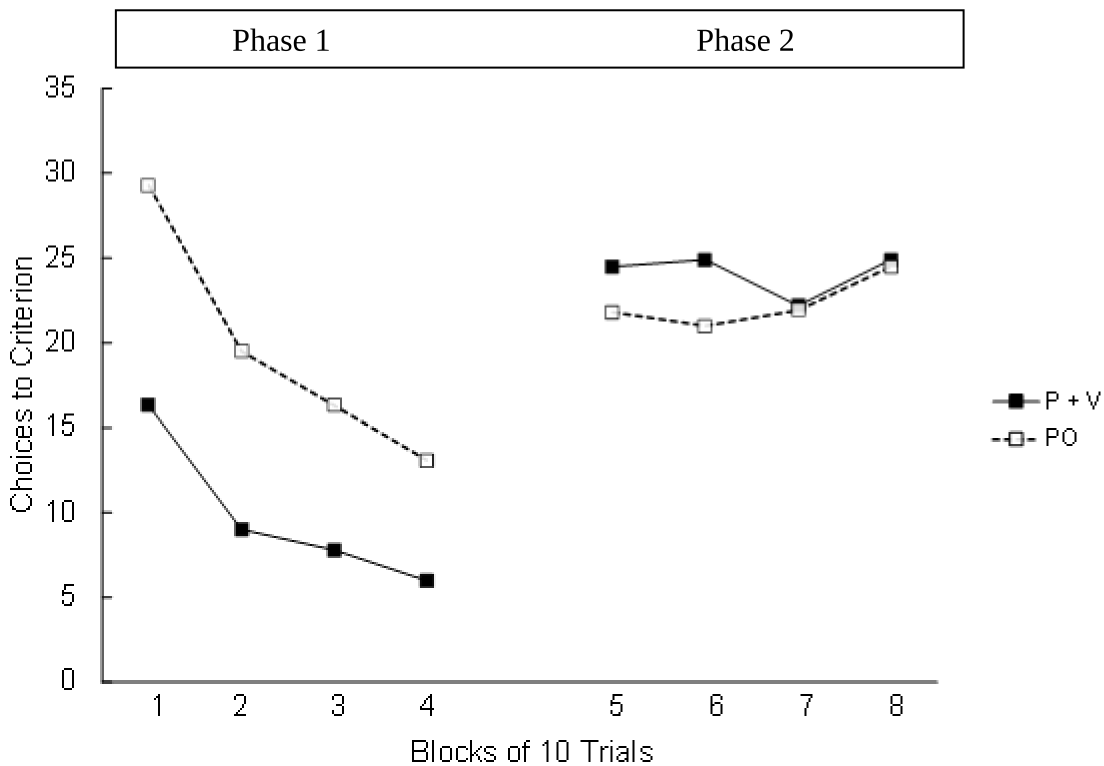

Figure 6. Mean CTC across all eight blocks of ten trials.

results indicated a significant main effect for condition, $F(1,10) = 29.32$, $p < .05$, partial $\eta^2 = .75$, such that the V+P rats were completing trials with significantly less looks. A significant main effect for the blocks of trials was also found, $F(3,30) = 63.02$, $p < .05$, partial $\eta^2 = .86$. The condition by block interaction was found to be insignificant, $F(3,30) = 3.21$, $p > .05$, partial $\eta^2 = .24$. A summary of the analysis can be found in Appendix A. Independent samples *t* tests were then conducted for each of the blocks of trials. The results indicated that the V+P group performed significantly better than the PO group over Block 1 (Trials 1 to 10), $t(10) =3.79$, $p < .05$, Block 2 (Trials 11 to 20), $t(10) = 5.17$, $p < .05$ and Block 3 (Trials 21 to 30), $t(10) = 5.10$, $p < .05$.

In Phase 2, the CTCs of both groups increased. V+P and PO rats' CTCs were very similar. A 2 x 4 mixed ANOVA was also conducted for Phase 2 with condition (V + P, PO) as the between-subjects factor and the last four blocks of 10 trials as the within-subjects factor. The results indicated a statistically insignificant main effect for condition, $F(1,10) = 3.99$, $p > .05$, partial $\eta^2 = .29$. The main effect for blocks of trials was also found to be statistically insignificant, $F(3,30) = 1.03$, $p > .05$, partial $\eta^2 = .03$. The condition by block interaction was also found to be statistically insignificant, $F(3,30) = 0.76$, $p > .05$, partial $\eta^2 = .07$. These results indicate that all rats performed at the same rate during each block of Phase 2, regardless of their condition. A summary of the analysis can be found in Appendix B.

A third ANOVA was completed in order to group data together across the two phases of 40 trials. In doing so, the data was able to be interpreted in a more general manner, which is especially important given the drastic change in conditions for the V+P rats. This mixed ANOVA was conducted using condition (V+P, PO) as the between-subjects factor and phases

(Phase 1, Phase 2) as the within-subjects factor. The results indicated a significant main effect for phases, $F(1,10) = 107.48$, $p < .05$, partial $\eta^2 = .92$. The main effect for condition was also found to be significant, $F(1,10) = 11.25$, $p < .05$, partial $\eta^2 = .53$. The phase by condition interaction was also found to be significant, $F(1,10) = 50.62$, $p < .05$, partial $\eta^2 = .84$. A summary of the analysis can be found in Appendix C.

Discussion

The present experiment succeeded in replicating the results of Brown, Yang, and DiGian's (2002) experiment with a more-complex spatial pattern. During Phase 1, all rats' performance improved over time with the V+P rats outperforming the PO rats during Blocks 1-3. During Phase 2, all rats' performance decreased. The third ANOVA found a significant difference between Phase 1 and Phase 2 scores regardless of condition. The V+P rats' performance decreased to a greater extent than the PO rats such that both groups performed at the same level during Phase 2. The main difference between the present results and the original Brown, Yang and DiGian (2002) study is the PO rats' decrease in performance between Blocks 4 and 5.

Between Phase 1 and Phase 2 (Blocks 4 and 5), the PO rats' performance dropped significantly according to the data despite the apparent lack of change in procedures. Upon discovering this fact, the experimenter~~s~~ investigated whether a change in procedure had occurred between Blocks 4 and 5. No major changes in procedure were found. One experimenter tested the rats in a haphazard order during Block 4 but tested the rats in numerical order (as should have originally been done) during Block 5. However, this change in procedures is unlikely to have caused such a drastic change in performance.

PO rats were performing quite well, perhaps too well, by the end of Phase 1. A number of hypotheses may be advanced to explain these data. First, the rats may have been following the scent of the previous rats that had been tested during the same trial session because the same pattern was used for all rats during each trial session. Upon reflection, the pattern should have been randomly assigned and varied across all rats for a given trial session. The other possibility is that the rats were smelling where the cheese was located. This explanation is highly unlikely though, as the experimenters smeared every food cup of cheese before each trial session. It is important to note that this error does not preclude a clear conclusion. Despite the PO rats' decline in performance between phases, the V+P rats were able to perform at the same rate as the PO rats in Phase 2. This shows that the visual cues did not overshadow the spatial cues for the V+P rats.

The present study was able to demonstrate for the first time that rats are capable of learning a spatial pattern as complex as the diamond used here. In past research a 2 x 2 matrix pattern has been used with rats (Brown & Terrinoni, 1996; Brown, Yang & Digian, 2002). Using a square pattern to demonstrate spatial pattern learning is difficult because one could claim that the rats are checking the closest towers rather than learning a spatial pattern. A diamond pattern is different because there is an empty tower in the middle separating the baited towers. This non-goal tower makes the spatial pattern more spread out across the maze and also more confusing for the rats. Also, a diamond patten requires more effort on the rats' behalf because the diagonal space between towers is greater than the distance between adjacent towers. The fact that the rats were able to learn this more-complicated spatial pattern provides further evidence that rats possess cognitive maps. It also provides evidence that rats are able to possess more-elaborate cognitive maps than previously thought.

Future research could move in several different directions. It would be interesting to investigate how complex a spatial pattern must be before a rat cannot learn it. This could be done by replicating this experiment with various baiting patterns. The traditional food tower maze could be used or perhaps a more complex apparatus. By experimenting with increasingly-complex spatial patterns, the boundaries of rats' spatial learning capabilities could gradually be mapped out.

Time is also an important factor to consider. Replicating the current experiment over a longer period of time could be quite revealing. For example, the current study could be replicated with 200 trials, 100 trials per phase. It would be interesting to see if the V+P rats would still be able to perform as well as the PO rats in Phase 2. The extended period of time with the visual cues may prevent the rats from retaining the spatial pattern learning. In fact, replicating this experiment with various amounts of trials may also help in determining the boundaries of rats' cognitive abilities. That is, it could be determined at which point – how many trials it takes – for a rat to not be able to utilize their spatial pattern learning. However, one may find that that never happens, which would be much more interesting.

References

Brown, M.F., & Terrinoni, M. (1996). Control of choice by the spatial configuration of goals. *Journal of Experimental Psychology: Animal Behaviour Processes, 22,* 438-446.

Brown, M.F., Yang, S.Y., & DiGian, K.A. (2002). No evidence for overshadowing or facilitation of spatial learning by visual cues. *Animal Learning & Behavior, 30,* 363-375.

Cheng, K. (1986). A purely geometric module in the rat's spatial representation. *Cognition*, *23,* 149-178.

Clipperton, A., Cole, M., Peck, M. & Quirt, J. (2014). *Pattern cue and visual cue competition in a foraging task by rats.* Under Review.

Rescorla, R.A., & Wagner, A.R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A.H. Black & W.F. Prokasy (Eds.), *Classical conditioning II: Current research and theory*. New York: Appleton-Century-Crofts, 64-99.

Sturz, B.R., Kelly, D.M., & Brown, M.F. (2010). Facilitation of learning spatial relations among locations by visual cues: Generality across spatial configurations. *Animal Cognition, 13*, 341-349.

Appendix A

Table 1

Summary Table for 2 (Condition) x 4 (Blocks of 10 Trials) Analysis of Variance during Phase 1

Source	*SS*	*df*	*MS*	*F*	*p*
Condition	1157.39	1	1157.39	29.32	<0.05
Error	394.75	10	39.48		
Blocks of Trials	1191.88	3	397.29	63.02	<0.05
Condition*Blocks of Trials	60.69	3	20.23	3.21	<0.05
Error (trials)	189.12	30	6.30		

Appendix B

Table 2

Summary Table for 2 (Condition) x 4 (Blocks of 10 Trials) Analysis of Variance during Phase 2

Source	*SS*	*df*	*MS*	*F*	*p*
Condition	41.63	1	41.63	3.99	>0.05
Error	104.35	10	10.44		
Blocks of Trials	41.82	3	13.94	1.03	>0.05
Condition*Blocks of Trials	30.82	3	10.27	0.76	>0.05
Error (trials)	407.05	30	13.57		

Appendix C

Table 3

Summary Table for 2 (Condition) x 2 (Phases of 40 Trials) Analysis of Variance

Source	*SS*	*df*	*MS*	*F*	*p*
Condition	96.00	1	96.00	11.25	<0.05
Error	85.33	10	8.53		
Phase of Trials	433.50	1	433.50	107.48	<0.05
Condition*Phase of Trials	204.17	1	204.17	50.62	<0.05
Error (trials)	40.33	10	4.03		

Appendix D

Table 4

Summary of subjects' experimental history

Rat	Condition	Experimental History
1	2	Autoshaping: hand shaping of a lever pressing response in a Skinner box. Operant maintenance of lever pressing on a continuous reinforcement schedule and two successive sessions of extinction of lever pressing. Ten sessions of stimulus control training on a multiple (variable interval 28 s – extinction) schedule with a cue light on during the variable interval components and off during extinction. Rat began to routinely list to the side and was switched out for Rat 10. By the time of the current paper's experiment the rat had fully recovered its walking ability and was used for testing.
2	1	Same experimental history as Rat 1 with the addition of a foraging task on a 12-arm radial maze.
3	2	Same experimental history as Rat 2.
4	1	Same experimental history as Rat 2.
5	1	Same experimental history as Rat 2.
6	1	Same experimental history as Rat 2.
7	2	Same experimental history as Rat 2.
8	1	No experimental history.
9	2	No experimental history.
10	2	Foraging task on a 12-arm radial maze. Substitute for Rat 1.
11	1	No experimental history. Been on free-feed diet until experiment onset.
12	2	No experimental history. Been on free-feed diet until experiment onset.

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